IAC-05-D2.5.08

ADVANCED DEVELOPMENT PROJECTS FOR CONSTELLATION FROM THE NEXT GENERATION LAUNCH TECHNOLOGY PROGRAM ELEMENTS

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ABSTRACT

When United States President George W. Bush announced the Vision for Space Exploration in January 2004, twelve propulsion and launch system projects were being pursued in the Next Generation Launch Technology (NGLT) Program. These projects underwent a review for near-term relevance to the Vision. Subsequently, five projects were chosen as advanced development projects by NASA's Exploration Systems Mission Directorate (ESMD). These five projects were Auxiliary Propulsion, Integrated Powerhead Demonstrator, Propulsion Technology and Integration, Vehicle Subsystems, and Constellation University Institutes. Recently, an NGLT effort in Vehicle Structures was identified as a gap technology that was executed via the Advanced Development Projects Office within ESMD. For all of these advanced development projects, there is an emphasis on producing specific, near-term technical deliverables related to space transportation that constitute a subset of the promised NGLT capabilities. The purpose of this paper is to provide a brief description of the relevancy review process and provide a status of the aforementioned projects. For each project, the background, objectives, significant technical accomplishments, and future plans will be discussed. In contrast to many of the current ESMD activities, these areas are providing hardware and testing to further develop relevant technologies in support of the Vision for Space Exploration.

INTRODUCTION

On January 14, 2004, President George W. Bush announced a new Vision for Space Exploration (VSE).1 Included in the President's announcement guidelines, were specific including returning the Space Shuttle safely back to flight, completing the International Space Station (ISS) prior to retirement of the Space Shuttle, and development of a new space architecture to allow for robotic and human exploration beyond low Earth orbit, including extended stays on the Moon and human exploration of Mars. A schedule was included with these guidelines included ISS completion and Space Shuttle retirement in the 2010 timeframe, an operational Crew Exploration Vehicle (CEV) by 2014, and the first extended human expedition to the lunar surface as early as 2015, but no later than 2020.

Prior to the President's announcement, an active effort to develop future space transportation technologies was being pursued in NASA's Next Generation Launch Technology (NGLT) Program. This program was developing technologies needed for safe, routine space access for scientific, exploration, commerce, and national defense purposes. The NGLT Program was intended to bring an array of technologies to a state of readiness appropriate to facilitate

decisions near the end of the decade on whether or not to initiate a program for development of NASA's next generation of launch vehicles.² The program consisted of twelve projects (Figure 1), ranging from fundamental hightemperature materials research to full-scale engine system developments to scramjet flight tests. Investments were categorized into three segments of technology: namely, propulsion technology, systems engineering and analysis, and vehicle systems technology. Within each of these segments, a series of projects was being executed to create a meaningful portfolio of technically relevant work, based on the expected and varied requirements needed by nextgeneration, reusable space launch vehicles.

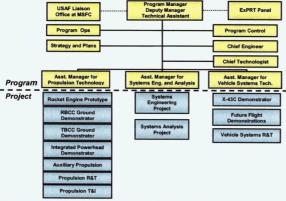


Figure 1. NGLT Program Organizational Chart.

Shortly after the President's announcement, NASA Administrator Sean O'Keefe appointed Rear Admiral (ret.) Craig Steidle as the Associate Administrator of the newly formed Office of Exploration Systems (later renamed the Exploration Systems Mission Directorate (ESMD)). One of the first actions by this office was a review of all the work currently being performed or funded by NASA in areas related to future space transportation. This paper focuses on the review process and results for the NGLT projects and, more importantly, a status of the projects that continued following this review.

RELEVANCE REVIEW

Process

Within 2 weeks of the VSE announcement, a process was initiated for reviewing the relevance of each NGLT project to the newly established

mission of the ESMD. Following a draft review by the three segment managers, a set of midterm recommendations for project disposition was generated. An external program review team was then convened to provide an independent relevance assessment recommendation for each project. This team was made up of senior Government and civilian aerospace executives with diverse and extensive experience in complex aerospace programs. The existing projects individually presented their case for relevance at the project, subproject, or task level, and the review team reviewed the information relative to the NASA VSE in the context of application to space transportation as a whole, not just for launch. At the appropriate (project, subproject, or task), recommendation was made for either (1) a potential scope (but not funding) transfer to other NASA Enterprises (such as Aeronautics), (2) not funding at this point, or (3) continuing funding under ESMD sponsorship, including any recommended scope changes as required. The criteria for assessing the existing NGLT projects included the applicability and benefits of the technology to future concepts and missions (including considerations infrastructure), achievability, schedule criticality with respect to supporting a given phase of the VSE, and, to a lesser extent, external commitments and congressional interest. Certain architectural elements for lunar and Mars exploration were assumed during the review, as well as key technology challenges in the CEV, human and cargo launch vehicles, human and cargo upper and transfer stages, and human, cargo, and robotic landers and ascent stages. The culmination of this effort was a briefing to ESMD management on March 11, 2004, that presented NGLT's recommendation for the disposition of each project or part thereof.

Results

Before identifying specific results of the relevancy review, two important recommendations were identified related to launch vehicles. First, fully reusable common booster Earth-to-orbit systems were eliminated. Because of the expectation that NASA would have low flight rates, a partnership would be needed to justify reusable elements and their

associated costs (including development), and none are currently foreseen. Second, hypersonic airbreathing propulsion was identified as not being applicable to the VSE for the foreseeable future. The rationale for that decision was that the payload capability was not sufficient for cargo launches and only minimally sufficient for a crew launch. Furthermore, substantial technical risk remains in demonstrating a viable launch system that incorporates hypersonic airbreathing propulsion to its envisioned eventual advantage over rocket propulsion. Therefore, it was deemed not fiscally realistic within the VSE.

In general, a good portion of the existing work was deemed relevant based on the assessment criteria. The specific recommendations for each category follow. The projects recommended for scope transfer to aeronautics were Turbine-Based Combination Cycle/Revolutionary Turbine Accelerator, X-43C, Future Flight Demonstrators, the hypersonic-unique elements Vehicle Systems Research Technology Project, and elements of the PR&T Project. All of these projects are associated with use of a hypersonic airbreathing propulsion system, and it was felt that these technology development activities should be performed under the auspices of the Aeronautics Enterprise until such time as they are sufficiently matured for providing a reusable, reliable, lower-cost option for crew launch.

The following tasked were not recommended for funding continuation: Rocket-Based Combined Cycle (RBCC) Engine; the design, fabrication, and testing of the Rocket Engine Prototype; a rocket engine risk mitigation activity with Northrop Grumman (TR-107) within the Propulsion Technology and Integration Project; and the launch aerodynamics, Guidance, Navigation, and Control (GN&C), and range elements of the Vehicle Systems Research and Technology Project. The rationale for stopping the RBCC effort included the fact that the activities are focused on a non-flight-weight. boilerplate test rig and that the technology has no aeronautics applications. The Rocket Engine Prototype and TR-107 activities were stopped because a new engine may not be required due

to the uncertain architectural dependency in the degree of heavy lift required for the VSE. The launch aerodynamics and GN&C were focused on two-stage, fully reusable, stage-separation which has no application to likely heavy-lift, Earth-to-orbit systems required for the VSE. Furthermore, these technical areas are very architecture-dependent. Finally, the elements focused on enabling low-cost launch range tracking system capabilities. The primary near-term users of this technology are the united States Air Force (USAF) and potentially Shuttle; so, given the timeline for new exploration launch systems, this technology can be delayed and restarted in the future.

The remaining NGLT tasks were recommended for continued funding and execution. They are Auxiliary Propulsion; Integrated Powerhead Demonstrator; Propulsion Technology and Integration; the University Institutes subproject of Propulsion Research and Technology; structures, Thermal Protection Systems (TPSs), and operable subsystems elements of the Vehicle Systems Research and Technology Project; and Systems Analysis, Engineering, and Integration. Figure 2 shows the results of the relevance review in the form of the reworked NGLT organizational chart. In short, some projects were stopped, some were re-scoped, and others were to be executed as planned.

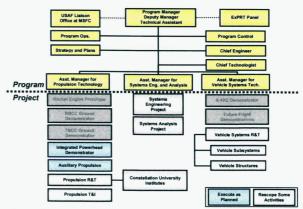


Figure 2. Organization Structure of NGLT Projects Following the Relevance Review.

INTEGRATED BASELINE REVIEW

On May 14, 2004, the technology projects that were approved for continuation from the

relevance review presented an Integrated Baseline Review (IBR) to the ESMD, where they were managed as part of the Constellation Advanced Development Program. The contents of the IBR formed the basis for execution of these projects and included specific technical performance metrics. Of the five projects included in the IBR, Auxiliary Propulsion and Integrated Powerhead Demonstrator were essentially unchanged from their project plans during original execution under the NGLT program. The Propulsion Technology and Integration Project was allowed to continue the efforts of four key propulsion technology activities that will be discussed in more detail later in the paper. The University Research, Engineering, and Technology (originally part of the Propulsion Research and Technology Project) were recast as the Constellation University Institutes, and Vehicle Subsystems emerged as a surviving piece from the Vehicle Systems Research and Technology Project. Another element of the Vehicle Systems Research and Technology Project in the technology area of Vehicle Structures was resurrected later in 2004. Each one of these new projects will be discussed in detail in the following section, including a description of the project, objectives, examples of significant technical accomplishments, and future plans.

ADVANCED DEVELOPMENT PROJECT STATUS

This section provides specific details on each of the remaining projects which are all being managed based on cost, technical performance, and risk management.

Auxiliary Propulsion

The Auxiliary Propulsion Project (APP) is developing technologies to reduce risk to ESMD vehicles through development of Cryogenic Fluid Management (CFM) technologies (including pressure control, mass gauging, and low-gravity liquid acquisition devices (LADs)); demonstration of Reaction Control Engine (RCE) operation with safe, operable, non-toxic propellants; and development and testing of prototype Auxiliary Propulsion System (APS) test bed hardware. Project management for APP

resides at NASA Marshall Space Flight Center (MSFC), and the performing centers include NASA Glenn Research Center (GRC) and NASA White Sands Test Facility (WSTF) as task execution partners.

In the CFM area, three tasks were addressed. First, mass gauging tests were performed to determine the ullage volume in a propellant tank from mass conservation of the non-condensable pressurant gas through the application of gas law methods. The tests were performed with liquid nitrogen (LN2) in the propellant tank and gaseous Helium (GHe) in the pressurant supply tank. Data was obtained at various test pressures up to 250 psi. Test results showed that there is significant GHe solubility in LN2 such that up to one third of the GHe present in the ullage could be in solution. Furthermore, when analytical models included liquid solubility effects, there was good agreement with experimental GHe consumption. Second, in the area of LAD technology, which has been demonstrated for storable propellants, the objective was to build a knowledge base for cryogenic propellants. In order to do this, inverted outflow tests needed to be performed, but screen channels required bubble point testing in a cryogen to prove the reliability of the hardware. Testing was performed using isopropyl alcohol and LN2 with a 200x1400 mesh screen, and the data indicates that this mesh size is the appropriate choice for LOX applications. Finally, an effort in Thermodynamic Vent System (TVS) technology was performed to provide in-space propellant tank pressure control because insulation systems cannot completely eliminate heat leak. A TVS offers many advantages over other potential methods including minimal power requirements, venting regardless of liquid or ullage location, and potential mass savings. Testing was performed using the Multi-purpose Hydrogen Test Bed at MSFC and results indicated that the hardware performed much better than predicted. with minimal propellant loss during vent cycling.

Non-toxic propellant RCE accomplishments included a series of LOX/ethanol tests at Aerojet in both vernier mode and primary mode. A total of 224 tests was conducted in vernier mode

accumulating over 9.000 seconds of operational time. In primary mode, 3,642 pulses were performed over 6 different pulse widths and 11 steady-state tests were conducted, with a total of 1.847 seconds of hot-fire test time. Figure 3 shows this engine during primary testing. Following these tests, Aerojet was granted a contract modification to deliver three prototype non-toxic propellant RCEs for testing at WSTF. These engines were fabricated and underwent acceptance testing in spring 2005 prior to delivery to WSTF. All three engines demonstrated high repeatability. While these acceptance tests were being performed, project management took the responsibility of writing an RCE operations manual for WSTF testing. Finally, a series of risks was assessed going into WSTF testing, including potential for leaks in the primary propellant valves, spark plug ceramic damage, combustion chamber damage from thermocouple welding, and the effects of purging versus not purging the engines to mitigate engine hard starts in a pulse mode.



Figure 3. Wide-angle and Close-up Views of a Single LOX/Ethanol RCE during Testing.

The culmination of this project will be the testing of the three RCEs in the WSTF Test Cell TS-401. The hardware installed in the test cell is known as the APS Test Bed. The APS Test Bed includes cryogenic propellant tanks, feed system and valves, a cryogenic accumulator/positive expulsion tank, a stinger box to house the engine components, and a RCS controller with a capability of controlling all three engines. Testing of these engines was expected to be completed by the end of Fiscal Year 2005 (FY05), but insertion of another engine test into the test cell has caused the APS test to be extended for several weeks into FY06. As of this writing, it is expected that cold-flow testing will begin by mid-September, followed by hot-fire testing a couple of weeks later. Figure 4 shows images of the installed hardware in the test cell.

Following the completion of the LOX/ethanol RCE tests, a logical follow-on effort would be to modify the APS Test Bed for LOX/methane RCE testing to provide an alternate propellant of interest to ESMD.



(a) APS Test Bed Tanks

(b) Elements of Three RCEs Inside Stinger Box

Figure 4. APS Test Bed Installation at WSTF Test Cell TS-401.

Integrated Powerhead Demonstrator

The Integrated Powerhead Demonstrator (IPD) Program began in 1994 at the Air Force Research Laboratory (AFRL) with the goal of designing, fabricating, and testing a 250k-lbthrust, full-flow, staged-combustion cycle engine. Currently, AFRL has contracts with Pratt Whitney Rocketdyne and Aerojet, and Space Act Agreements with Stennis Space Center (SSC) and MSFC to complete the execution of the project. AFRL has overall project lead responsibilities, MSFC serves as the technical lead and overall NASA lead for project management, and SSC is the test organization. The objectives of the project are to demonstrate the feasibility and benefits of the full-flow, staged-combustion cycle; provide key rocket component technology engine validation (including a channel wall nozzle; hydrostatic bearings; hot-isostatic-pressure-bonded, highchamber-pressure, main combustion chamber; gas-gas main injector; single-piece turbine blisk; oxygen-rich material development; and platelet injector design); and provide validation of design and analysis tools being used by the prime contractors.

Component testing of the oxygen turbopump and preburner was completed by October 2003, and the hydrogen turbopump and preburner component testing was completed by August 2004. Facility activation tests for preparing the systems at Cell 3 of the SSC E1 Test Stand have also been completed. On October 15, 2004, the IPD was successfully installed in the test cell (Figure 5). The IPD Test Readiness Review was held at SSC on January 20, 2005, and no major actions were identified. The first test in the series was a LOX cold shock test that occurred on February 10, 2005, and was followed 6 days later by a LH2 cold shock test. To date, the IPD has performed 6 successful startup sequence tests, and the latest test achieved approximately 90% power level at the peak of this starttransient test. Figure 6 shows images taken during a typical hot-fire test. A goal of the project is to attain a steady state power level of at least 80% before the test series is completed. It is expected that testing will be extended into FY06 until resources are expended. There is also a proposal to complete the entire test matrix and perform disassembly and inspection of some of the key components to understand durability for this type of engine cycle.



Figure 5. IPD installed at SSC E1 Test Stand, Cell 3.



Figure 6a. Visual Image Taken During the July 19, 2005, IPD Test, Start Sequence to ~50% Power Level.

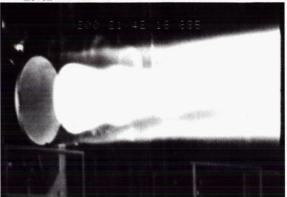


Figure 6b. Close-up of Nozzle Area with UV Filter Taken during the July 19, 2005, IPD Test, Start Sequence to ~50% Power Level.

Propulsion Technology and Integration

The Propulsion Technology and Integration (PT&I) Project is comprised of a set of heritage activities that began in programs either preceding the NGLT Program or that were created under NGLT. Each activity is an independent task with specific objectives and deliverables. These activities are in-house, NASA-led, technology maturation tasks that have potential application in a broad array of propulsion-related areas. Project management resides at MSFC, but significant technical performance is being overseen at GRC and NASA Kennedy Space Center (KSC). The objective of the project is to develop and propulsion demonstrate four key main technologies that support the VSE. They are development Combustion of GRCop-84,

Devices Injector Technologies, Propulsion High-Impact Avionics Technologies (PHIAT), and miniaturized leak detection sensors.

The first technology is materials development of a copper alloy known as GRCop-84, developed at GRC for use in regeneratively cooled rocket engines. This alloy possesses an excellent combination of conductivity, thermal expansion, strength, creep resistance, ductility, and lowcycle fatigue life. There are three objectives of this activity. The first objective is to develop all technologies required to scale-up the production of GRCop-84 to a capacity and size sufficient for a full-scale Main Combustion Chamber (MCC). The second objective is to reduce costs and improve performance and durability of future engines by utilizing GRCop-84's superior properties compared to the currently used alloy, NARLoy-Z. The final objective is to reduce the time to manufacture a coated liner from years to months. Accomplishments in this area include the manufacture of several thrust chamber liners out of GRCop-84 to be compared with ones made of NARLoy-Z. The GRCop-84 liners are either fabricated from two half cylinders that were friction stir welded at MSFC, metal spun, and coated with a vacuum plasma spray (VPS) film or directly vacuum plasma sprayed onto a mandrel with the proper contour for the hot wall. Hot-fire cycle testing was performed on a VPS subscale (5,000 pound class) engines (Figure 7) and the VPS GRCop-84 liner outperformed the NARLoy-Z liner from a materials and engine performance standpoint. Furthermore, friction stir weld has been successfully applied to GRCop-84 sheets (0.043" thick) with weld strengths in excess of 95% of the parent material (Figure 8).

The second task is known as Combustion Devices Injector Technologies (CDIT). The purpose of CDIT is to develop injector technology and modeling capability required for cryogenic upper stage engines. There are three main objectives to CDIT: (1) to reduce local peak combustion chamber heat flux due to the injector, (2) to improve injector ignitability, and (3) to improve combustion stability margins. The heat-flux reduction task is being performed jointly by MSFC and Penn State University.

MSFC provides analysis and design of singleelement and Penn State fabricates and tests them.



Figure 7 (a) Image of Various Engine Sizes and Types.



Figure 7 (b) Lner in Hot-Fire Cycle Testing.

Figure 7. GRCop-84 Main Combustion Chamber Applications.

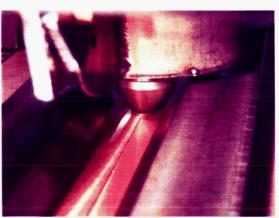


Figure 8. Demonstration of GRCop-84 thin plate friction stir welding.

Eight injector designs have been tested and over 100 hot-fire tests have been completed. Chamber pressures varied from 300 to 1,200 psia with mixture ratios of 5, 6, and 6.5 (Figure 9). The test data is then used by MSFC to validate the heat-flux predictive capability from Computational Fluid Dynamics (CFD) tools for use in the injector design process. The ignition task is being performed by Purdue University and includes both CFD analysis (to predict inspace ignition conditions) and experimental tests (simulating pre-ignition mixing conditions using inert simulants-nitrogen and helium). Again, the test data is used to validate design tools for use in future ignition design efforts. Finally, the stability task brings together an analysis tool developed by the University of Tennessee Space Institute and an injection-coupled stability model developed by MSFC.

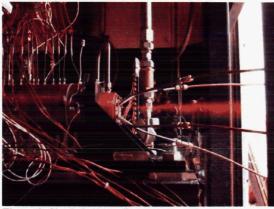


Figure 9. Single Injector Element Hot-Fire Testing.

Third, the PHIAT task seeks to develop advanced avionics technologies that will increase reliability and safety of propulsion and avionics systems while decreasing development, sustaining, and operations costs. Furthermore, the advanced technologies seek to reduce overall avionics and propulsion systems weight. One of the primary accomplishments from the task is the development of the Integrated Safety-Critical Advanced Avionics for Communication and Control (ISAACC) system (Figure 10). This system uses Time-Triggered Protocol for hard real-time communication between components in a distributed architecture along with smart sensor and intelligent actuator controller boards. Modularity is implemented at all levels to

facilitate high reusability, flexibility, and scalability. Distributed intelligence allows implementation of complex functionality using processors of moderate capability (i.e., currently available radiation-hardened processors). Hotswap capability improves maintainability while plug-and-play transducers reduce the cost of and unique software changes software configurations. The PHIAT team successfully conducted a simulated Reaction Control System (RCS) test on August 17, 2005, using the ISAACC system, involving the simulated firing of a thruster using LN2. In addition, a balanced flow meter is being developed that has performance characteristics equivalent Venturi meters but without the pressure drop. System demonstration with cryogens is expected by the end of FY05.



Figure 10. ISAACC System.

Finally, miniaturized leak detection sensors are being developed and demonstrated to provide real-time, leak detection technology for oxygen, hydrogen, and hydrocarbons in a postage-stampsized sensor array to improve safety and operational readiness when incorporated with vehicle health management. The two primary efforts included in this task are development of the sensors and hardware integration/system testing. The former includes optimizing sensor response and power consumption, and the latter includes system miniaturization, electronics, packaging, and wireless output. As shown in Figure 11, the three sensors and associated circuitry are indeed postage-stamp-sized and the overall system including power supply and antenna fit into an area of approximately one cubic inch.

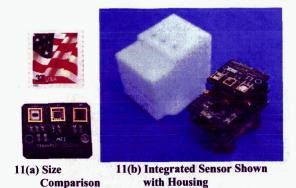


Figure 11. Miniaturized Leak Detection Sensors.

Although there are no specific plans to continue any of the activities, the project is prepared to support technology maturation or risk reduction in any of these areas as required for the VSE as demonstrated by proven project execution.

Vehicle Subsystems

The Vehicle Subsystems Project originated under the program that preceded NGLT and transitioned to being an NGLT subproject under the Vehicle Systems Research and Technology Project. Project management resides at GRC, while MSFC, KSC, and Johnson Space Center (JSC) all contribute to the project's execution. The objective of the Vehicle Subsystems Project to develop and demonstrate vehicle subsystems in the areas of actuators and fuel cells and other advanced power technologies that provide a significant reduction in the cost of space transportation systems while dramatically improving their safety and operability. This project will help enable all-electric launch and space vehicles through actuator mechanical systems technologies and power component technologies. The current project will complete current actuator and power contracts and related activities through FY06.

The actuator element seeks to eliminate vehicle hydraulic systems and incorporate electric actuator technologies in the form of electromechanical and electro-hydrostatic actuators (EHAs). A prototype EHA has been designed, fabricated, and assembled as part of this project (Figure 12). The EHA consists of one hydraulic piston/cylinder powered by four pump/motor/controller strings. The hydraulic

fluid is for power transmission, but there are no external fluid interfaces, just electrical and structural interfaces. This prototype EHA demonstrated that a large (50 horsepower) twofault tolerant electric actuator is feasible. It is the largest, most powerful EHA ever built. Furthermore. the four **EHA** internal motor/pumps are joined together in such a way that the flow from all four internal hydraulic pumps is added together to drive the actuator, making this the first flow-summed EHA as well.



Figure 12. Prototype EHA.

The power component element is providing application of advanced energy storage and power generation, management and distribution technologies (such as lithium batteries and nontoxic turbine power units (TPUs), as well as maturation of Proton Exchange Membrane (PEM) fuel cell power plants for space vehicle applications. The objectives of the lithium battery activity are to store electrical energy for transient loads, augment power generation system capability, increase power density or energy density and life, incorporate health monitoring, and reduce life cycle cost. The significance of this effort is to reduce risk through the characterization and down-selection of battery cell vendors, trading off cost, performance, life, and path-to-flight. The TPU effort is expect to provide a non-toxic (hydrogen/oxygen) TPU with a 270-Vdc, 142kW peak output, increasing safety and reliability relative to existing hydrazine auxiliary power units and reducing life cycle cost. A photograph of a brassboard TPU developed under this project is shown in Figure 13. TPU hot-gas testing has been successfully completed, and TPU thermal stability, hot restart, and TPU speed control and power generation with hot-gas (hydrogen and oxygen reaction) tests have been demonstrated. However, hot-gas test stand limitations allowed only 90 kW as the maximum load obtainable for current test stand setup.



Figure 13. Brassboard TPU.

Finally, the PEM fuel cell effort seeks to demonstrate improved capability over the existing Space Shuttle alkaline fuel cell powerplant in the areas of increased power, longer life, significantly reduced ground processing, and a reduction in hazardous materials and critical failure modes. Initial testing of a breadboard PEM fuel cell unit has logged over 1,000 operating hours, and a membrane electrode assembly endurance test with an improved membrane has achieved over 6,000 hours toward an expected life of 10,000 hours. An engineering model of a PEM fuel cell has been built and delivered to NASA (Figure 14).

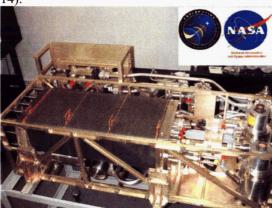


Figure 14. PEMFuel Cell Engineering Model.

Constellation University Institutes

The Constellation University Institutes Project (CUIP) contains three institutes that were originally subprojects under the Propulsion Technology Pillar of NGLT. These three

institutes, shown in Figure 15, are the Institute for Future Space Transport, the Space Vehicle Technology Institute, and the Rocket Engine Advancement Program Institute.

Institute for Future Space Transport



Space Vehicle Technology Institute



Rocket Engine Advancement Program Institute



Auburn Tuskegee
Figure 15. University Participation in the Constellation
University Institutes.

Each institute has a lead university (first university shown) and multiple supporting university structure. The overarching objectives of the CUIP are to perform research and development that addresses critical Constellation needs, to enhance and broaden the ability of the

nation's universities to meet the needs of NASA's programs, to expand the nation's talent base for NASA mission-related research and development and technology maturation and to strengthen NASA's ties to academia through long-term, directed, and sustained investment

This project oversees the research efforts of the institutes, fosters collaboration between the universities and NASA/DoD/Industry, manages all review processes, and performs financial management. Project management resides at GRC, while NASA Ames Research Center (ARC), GRC, NASA Langley Research Center (LaRC), and MSFC all contribute technical interaction on a task-by-task basis. Another key element of CUIP, in addition to the university researchers and the NASA team, is an advisory board consisting of Air Force and industry representatives who act as conduits to their respective organizations and spokespeople, offer guidance to and establish/ refine partnerships between their organizations and the university institute researchers.

CUIP is focused on being relevant to Constellation needs. As the three institutes transitioned to ESMD (and thereby the CUIP), a technical refocus was required; the guiding principle of this refocus was to build up capability in several key technical areas, making the university institutes the place to go for first principles solutions to problems in those key areas. These key areas are thrust chamber assemblies, propellant storage and delivery, vehicle thermal structures. reentry aerothermodynamics, systems analysis, and education. Moreover, during and subsequent to the refocus, a heavy emphasis has been placed on a virtual, rather than contractual, combination of the three institutes: deriving additional effectiveness from multiple universities being engaged in related research within a particular technical area, regardless of institute boundaries.

The CUIP currently consists of 52 tasks. The level of involvement and proliferation of meaningful output only in the form of degrees granted and publications is shown in Figure 16. Technical accomplishments and customer deliverables, which constitute the heart of CUIP,

are too numerous to discuss in this paper, but they have been showcased in recent AIAA Joint Propulsion Conferences.

	Institute for Future Space Transport (\$3M)		Rocket Engine Advancement Program (\$1M)
Key Personnel	28 Faculty	30 Faculty and Affiliated Researchers	17 Faculty and Staff
Current Students Supported	3 BS 10 MS 41 PhD	16 MS 34 PhD	14 MS 5 PhD
Degrees Granted	3 BS 13 MS 6 PhD	1 BS 24 MS 3 PhD	1 BS 6 MS
Publications	120 workshop, conference, and archival publications	178 workshop, conference, and archival publications	20 conference publications

Figure 16. Summary of CUIP Progress.

Vehicle Structures

While not included in the NGLT relevance review, the ESMD reinstated a series of tasks related to vehicle structures in February 2005 after additional requirement definition had been performed showing a need for this under Advanced Development. The Vehicle Structures Project, managed by LaRC and executed by LaRC and MSFC, consists of four tasks. The first task, Composite Tank Non-Destructive **Evaluation** (NDE) and Material Characterization, will develop cryotank NDE standards and end-of-life material properties for LH2 applications. The second task, Thermal-Acoustic Fatigue Analysis, will be used to document and release previously developed thermal-acoustic fatigue computer codes. Figure 17 shows a sample thermal-acoustic response of a Carbon-Carbon TPS structure. The third task. Integrated Aerothermal/Structural-Thermal Analysis and Design, will develop a rapid, integrated, variable-fidelity methodology for aero/aerothermal loads and automated TPS selection and sizing for contractor use and government insight into trade studies and preliminary design of exploration entry vehicles. The final task, Thermal Deflection of Metallic TPS, will be used to characterize effects of hightemperature flow on metallic structures deformation, and the subsequent effect on

boundary-layer transition and aero-heating rates. The current schedule anticipates the first task to extend into FY06, while the final three tasks should be completed by the end of FY05.

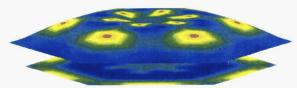


Figure 17. An Example of Thermal-Acoustic Response of Carbon-Carbon TPS Structure.

SUMMARY/CONCLUSIONS

The purpose of this paper was to present a status of the projects from the former Next Generation Launch Technology Program that were continued following a relevance review by Systems Mission NASA's **Exploration** Directorate. These Advanced Development Projects are providing specific technical deliverables in the form of near-term hardware and testing to further develop relevant the Vision for Space technologies for Exploration. Continued significant effort and outstanding execution and results for all project objectives have been demonstrated before and after the projects were re-baselined, many of them with multi-center project management and execution teams.

ACKNOWLEDGEMENTS

The authors would like to thank the following individuals for their expertise at leading and managing their respective projects and for providing a review of the contents of this paper: Philip Best, Gary Genge, David Glass, Scott Graham, Steven Kurtz, Peter Mazurkivich, Claudia Meyer, Jeffry Rybak, Margaret Tuma, Ronald Unger, and Kenneth Vadasy. The review of this paper by Richard Tyson is also greatly appreciated.

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